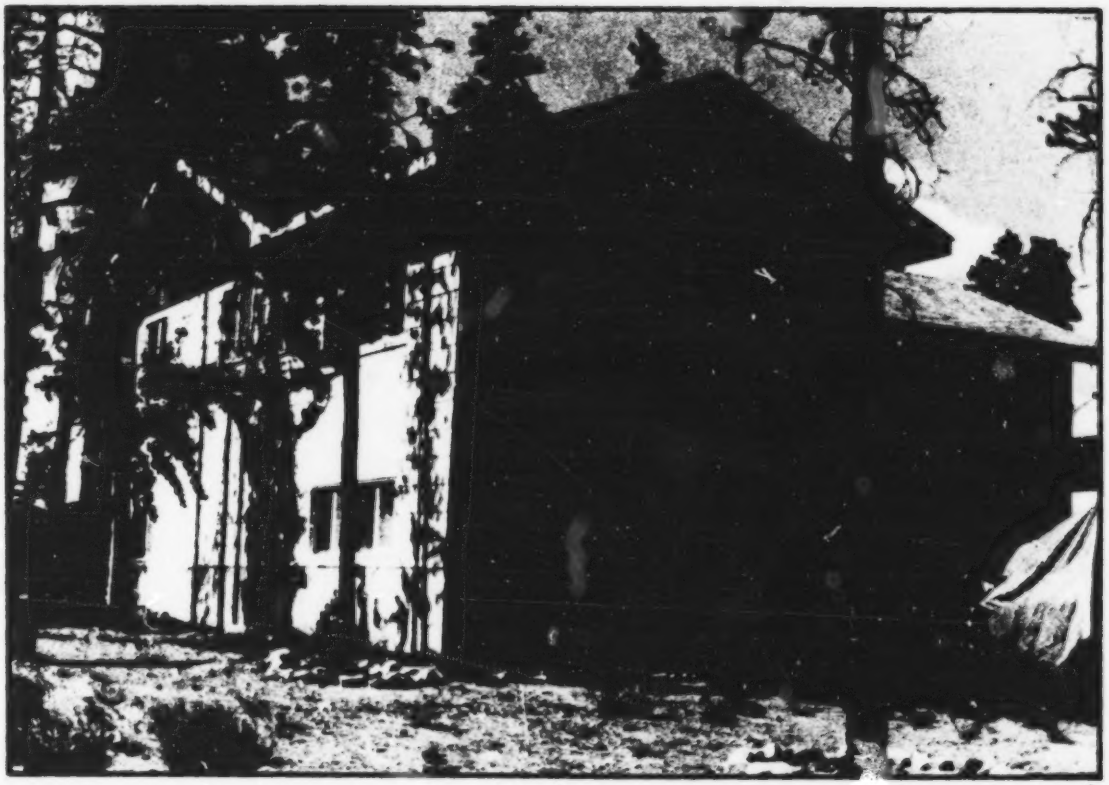
CREDA

New Home Construction: Yukon College

April/85

CREDA is a program which has been jointly funded by Energy, Mines and Resources, Canada and the Yukon Government, Department of Economic Development and Tourism. For more information or copies of reports contact the Energy and Mines Branch, Yukon Government, Box 2703, Whitehorse, Y1A 2C6.



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FOREWORD

The availability of secure and affordable energy supplies is a subject of national concern. Our primary energy sources are becoming more costly and less accessible. However, Canada has both the resources and technical expertise needed to develop renewable and alternate sources of energy.

The governments of Yukon and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement as one means of pursuing this end. Cost shared by the territorial and federal governments, CREDA has a budget of $3.3 million and is dedicated to the development and demonstration of conservation and renewable energy technologies.

The objectives of CREDA are:

- to develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently,
- to develop broad public awareness of the potential of renewable energy and conservation technology,
- to provide opportunities for the commercial application of the technologies,
- to create economic spin-off benefits for manufacturing, industry and commerce and
- to create employment in new or existing energy-related industries.

The demonstration project which is discussed in this report was an important attempt to teach carpentry students at the Yukon College the knowledge and technical expertise associated with energy conservation building construction. A large proportion of Canada's energy resources are expended in residential heating. This project and others undertaken in different jurisdictions might significantly reduce the amount of fuel energy required to heat poorly constructed homes.

EXECUTIVE SUMMARY

The following report demonstrates the economic viability of constructing an energy efficient home as a training program for students in the carpentry and electrical courses at the Yukon College. The demonstration project incorporated energy conservation measures into the construction design of an energy efficient single family dwelling to provide direct training for the students in the carpentry course.

During the 1980/81 college year, the students built the house located at #2 Chestnut Place in the Porter Creek subdivision in Whitehorse, Yukon. The major energy conservation features included the installation of an air-vapour barrier, construction of "double stud walls" to accommodate additional insulation, insulation of the basement floor and provision of a Jetstream wood furnace to heat both the air and domestic hot water. Other features included the redesign of window size and shape, thermal window shutters and triple glazing on the north facing windows.

These measures were estimated to cost approximately $7,800; however, the actual costs skyrocketted upwards to $30,000. The reason for this is the result of costly improper installation of the Jetstream furnace. It was necessary to hire a consultant familiar with the heating appliance to redesign the system in order for it to work.

Because of the problems associated with installing the wood furnace and because the tenants occupying the house did not maintain fuel records,

it is impossible to assess the energy savings at this time. The new owner, however, estimated that approximately six cords of wood would be required to heat the house during an average temperature winter season.

The most significant result of the project is to demonstrate the need to provide local contractors with technical training prior to or along with the introduction of innovative energy efficient technology.

Résumé pour l'exécutif

Le rapport suivant démontre la viabilité économique de la construction d'une maison à très haut rendement énergétique, en tant que programme de formation pour des étudiants suivant des cours en charpenterie et en électricité au Collège Yukon. Le projet de démonstration a incorporé des mesures visant à la conservation de l'énergie dans les plans de construction d'une maison unifamiliale à très haut rendement énergétique dans le but de fournir aux étudiants de la formation pratique dans le cours de charpenterie.

Durant l'année scolaire 1980-81, les étudiants ont construit la maison situé au 2 Chestnut Place dans le quartier résidentiel de Porter Creek à Whitehorse au Yukon. Les principales mesures visant à la conservation de l'énergie incluaient l'installation d'un coupe-vapeur pour rendre la maison étanche à l'air, la construction de murs à double cloisons pour permettre la pose de matériaux isolants additionnels, l'isolation du plancher du sous-sol et l'installation d'une chaudière au bois "Jetstream" qui sert à chauffer l'air et l'eau de la maison. Les autres mesures comprenaient la modification de la forme et de la grandeur des fenêtres, l'utilisation de volets thermiques et de fenêtres à triple vitrail sur le côté nord de la maison.

Au départ, on avait estimé que ces mesures coûteraient environ 7.800$; cependant, les coûts réels ont monté en flèche pour atteindre les 30.000$. La raison pour cette escalade des coûts est que la chaudière Jetstream n'a pas été installée correctement et ceci a résulté en des coûts additionnels. Il a fallu, en effet, engager un conseiller qui soit familier avec la chaudière en question et il a du élaboré de nouveaux plans pour le système de chauffage afin que celui-ce devienne opérationnel.

A cause des problèmes reliés à l'installation de la chaudière au bois et parce que les premiers occupants de la maison n'ont pas

pris en note leur consommation de bois, il est impossible d'évaluer en ce moment les économies d'énergie réalisées. Cependant, le nouveau propriétaire a estimé qu'il faudra approximativement six cordes de bois pour chauffer la maison durant une saison hivernale aux températures moyennes.

Le résultat le plus significatif de ce projet a été de démontrer qu'il importe de fournir aux entrepreneurs locaux une formation technique avant ou pendant l'introduction de nouvelle technologie à très haut rendement énergétique.

INTRODUCTION

The Yukon Government's Department of Education, in conjunction with the Canada/Yukon Conservation and Renewable Energy Demonstration Program, undertook a project for the purpose of training carpentry students at the Yukon College in energy conservation construction methods and technology.

As part of the practical training, the students who enroll each year in the Construction Carpentry course at the Yukon College build a single family house in Whitehorse, Yukon. These construction projects serve as an opportunity for students to practice, in a real life situation and under the direct supervision of instructors, the theories and technical skills learned in the classroom. Once completed, the house is then sold on the open market.

During the 1980/81 college year, the students built the house located at #2 Chestnut Place in the Porter Creek subdivision. This particular house design was modified to incorporate several energy conservation features. These include double stud walls, installation of an air-vapour barrier and a Jetstream wood furnace to heat the house and domestic hot water supply.

The demonstration project was undertaken to disseminate technical information to the general public and local building contractors as well as to the students. The building site was located on an accessible street and specific arrangements were made for public viewing. For

example, tradespersons, professionals and the general public were allowed free access during all building phases. Once construction was completed and the building occupied, it was available for inspections only on weekends upon appointment. As well, records of the building costs and heating requirements are available for review.

PROJECT DESCRIPTION

The house design was completed prior to the implementation of the CREDA program; therefore, there are several minor disadvantages of the house design in terms of energy efficiency. For example, the faces southwest instead of directly south to maximize solar heat penetration and the area of windows on the non-south elevations is perhaps a little excessive. The siting of the house on Lot 1231 is diagrammed in Figure 1.

Excavation for the basement and pouring for the footings took place in June, 1980. Actual construction started in September, 1980 and the house was completed in June, 1981. The energy conservation features which were incorporated into the construction program are listed below and each feature is discussed in some detail.

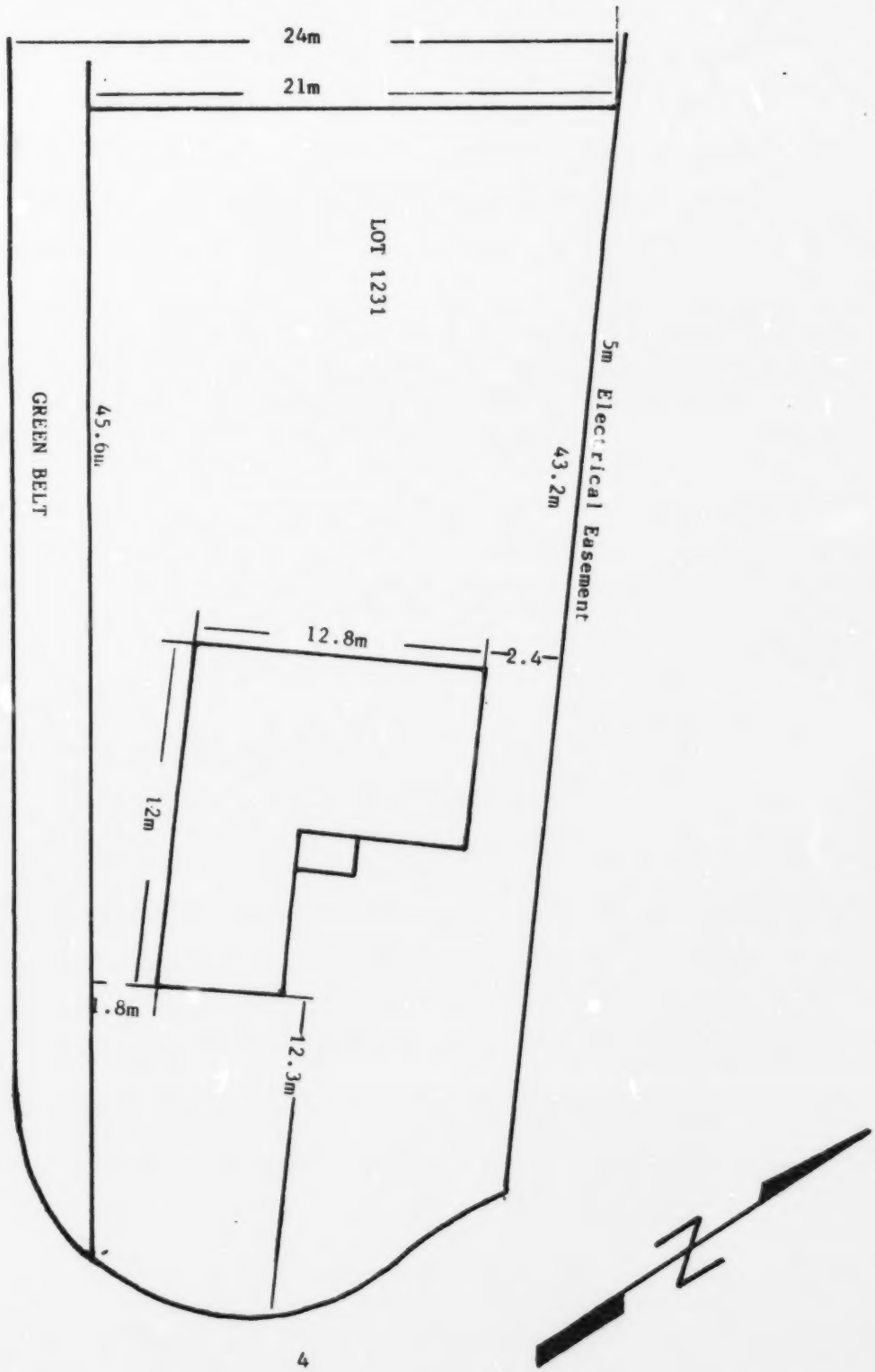
Air-Vapour Barrier

FEATURE: INSTALL THE AIR-VAPOUR BARRIER WITH THE UTMOST CARE TO ENSURE A CONTINUOUS SEAL.

Infiltration and exfiltration of air is the largest single cause of heat loss in a dwelling, often accounting for 50 percent of the total loss. The sealing of an air-vapour barrier where it meets the floors and around the windows, electrical boxes, ceiling fixtures, etc. is a difficult problem but one which can be solved in part by careful installation and by using modern caulking materials such as "geocel". These materials do not harden and crack with age.

FIGURE 1

SITE PLAN



In particular, the barrier should be sealed to the floor with the use of soft caulking. The same caulking should be used to seal around all windows. When cutting the barrier away from the windows, enough of the polyethylene must be left to be folded down and sealed to the framing members. Soft caulking should also be used to seal each electrical switch and fixture.

All air ducts must be sealed to prevent leakage of air. This is particularly important where the warm air duct passes through the garage. Leakage of warm moist air into the insulation can result in serious condensation problems.

To increase the airtightness of the house, weather stripping was applied around the doors and an oil-based paint was applied to the drywall to help prevent vapour from passing through the wall board itself.

The above mentioned points are of paramount importance. An inadequate air and vapour seal will nullify much of the beneficial effects of increasing the fibreglass insulation.

It was anticipated that a high degree of airtightness of the building would be achieved through the proper installation of the air-vapour barrier. Therefore, an air-to-air heat exchanger was installed to recover heat from ventilation air required for the building.

Increased Insulation

FEATURE: INCREASED INSULATION, PARTICULARLY ON THE NORTH-FACING WALL AND BASEMENT FLOOR.

Structural changes were necessary to the original house design in order to accommodate the desired increases in insulation levels. This involved a change from the customary 2 x 6 size single wall studding to provide two standard stud walls of 2 x 4 studding tied together by plywood top and bottom plates. The total width of the wall is determined by the width of these plates. This method of energy efficient construction is generally referred to as "double stud walls".

In the publication, Energy-Efficient Housing Construction, Central Mortgage and Housing Corporation describe the various techniques employed in energy efficient housing construction (1982 : 51 and 52). Double stud walls are described as follows:

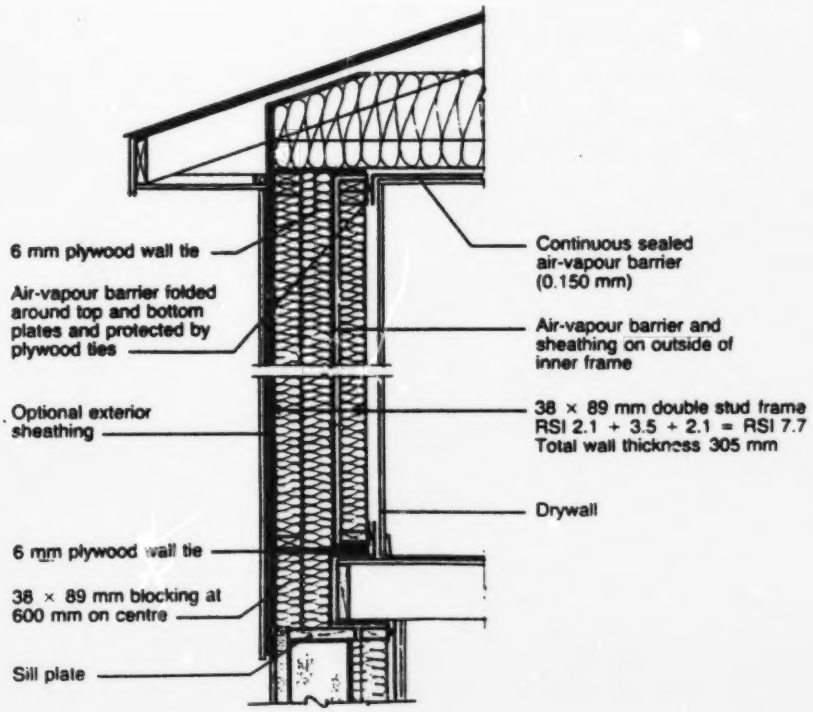
> 1. Double stud walls consist of two standard stud walls tied together by plywood top and bottom plates. The total width of the wall is determined by the width of these plates. The inner of the two stud walls is the structural wall.
>
> 2. The wall is constructed in the conventional fashion, in the sense that it is constructed horizontally on the floor and then tipped up and into place. The inner wall is constructed first, including both top plates. The polyethylene air-vapour barrier is then placed on top, using EE joining and sealing techniques . . . . The sheathing is then nailed on in the conventional manner, thereby protecting the barrier from mishandling and wind effects. Care should be taken not to damage the barrier when cutting the sheathing.

3. The outer stud wall is built next, directly on top of the inner wall. Using temporary spacer blocks, nail the two walls together using the top and bottom plywood plates. Apart from tying the wall together, these plates protect the air-vapour barrier.

4. Blocking is next installed on the sill plate . . . [See Figure 2]. Note that this requires an unusual positioning of the first floor header, near the inside edge of the sill plate. This blocking serves as a support for the outer wall and as a nailing surface for the finishing material.

FIGURE 2

DOUBLE STUD WALL


6 mm plywood wall tie
Air-vapour barrier folded around top and bottom plates and protected by plywood ties
Optional exterior sheathing
6 mm plywood wall tie
38 × 89 mm blocking at 600 mm on centre
Sill plate
Continuous sealed air-vapour barrier (0.150 mm)
Air-vapour barrier and sheathing on outside of inner frame
38 × 89 mm double stud frame
RSI 2.1 + 3.5 + 2.1 = RSI 7.7
Total wall thickness 305 mm
Drywall

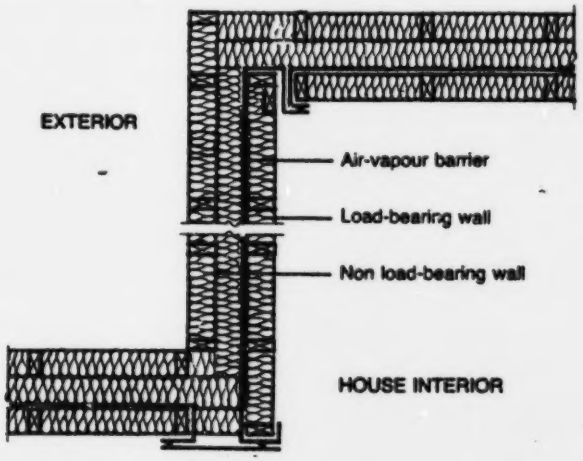
5. The wall section is tilted up and put in place (and, in addition, is nailed to the blocking). The air-vapour barrier flaps are stapled to the inner face of the top and bottom plates to prevent damage; later, these flaps will be sealed to the header and ceiling air-vapour barriers using standard EE techniques . . . The outer two cavities of the wall can now be insulated with fibreglass batts when desired. Wiring can be installed inside the air-vapour barrier, without causing damage, before the third layer of insulation is installed.

6. Some houses with this wall design have experienced movement of the outer frame. This is probably due to the fact that the inner frame is much warmer than the outer frame, and so has a higher moisture content. In some double frame wall designs, builders install plywood bracing between the two frames at a few points.

7. Other varieties of double stud wall have been built. Whatever double wall technique is chosen, care should be taken to seal the air-vapour barrier properly at corners . . . [See Figure 3]. Windows, doors, pipes, vents, interior partitions, and other breaks also require sealing . . .

FIGURE 3

CORNERS IN DOUBLE WALL CONSTRUCTION



In the demonstration project, the need for higher levels of insulation was recognized, especially on the north-facing wall. The double stud system incorporating off-set 2 x 4's provides a 25 cm wide north wall while the other walls are constructed 20 cm deep. The northern wall consists of a double wall of 2 x 10 plates with 2 x 4 studs fastened in alternate positions which provides a continuous wall of RSI 3.5 insulation (15 cm) on the outside and a continuous wall of RSI 1.8 insulation (8.75 cm) on the inside.

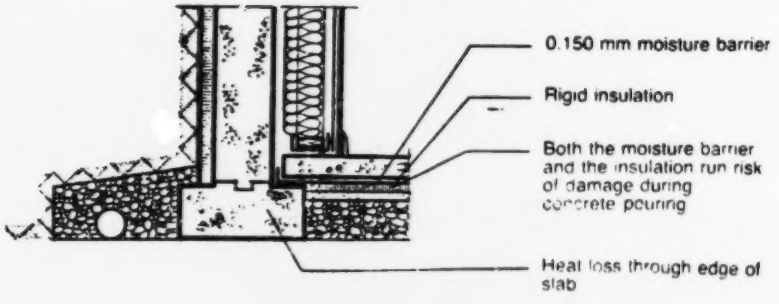
The basement floor was also insulated. Five cm thick styrofoam was installed to act as a frost shield for a .6 m width around the footings of the building. Also, five cm thick polystyrene was placed under the basement floor. In the same publication mentioned above, Central Mortgage and Housing Corporation describe the method for insulating the basement floor (1982 : 39).

> 1. RSI values equal to or greater . . . [RSI 1.8]. Rigid polystyrene insulation is recommended.
>
> 2. The insulation is laid down on the compacted fill and covered with a 0.150 mm polyethylene moisture barrier. A layer of sand may next be placed on top of the polyethylene to facilitate curing of the concrete slab, which is poured on top of the sand.
>
> 3. From a practical point of view it is very difficult to do all this properly. When the slab is being poured, the concrete is moved around with wheelbarrows and shovels; there is a considerable risk of damaging either the insulation or the moisture barrier. If extra care is taken during slab pouring, it might be possible to retain the integrity of the moisture barrier and insulation.

4. If intact, the moisture barrier can also act as an air-vapour barrier and can, in theory, be joined to the main house air-vapour barrier (if the basement wall is insulated inside) to give a completely sealed envelope. In practice, the moisture barrier will be shredded where it projects above the edge of the slab, and there will be little chance of achieving an airtight joint. Consequently, it makes most sense to terminate the moisture barrier at the footing . . . [See Figure 4].

FIGURE 4

INSULATING BASEMENT FLOORS


0.150 mm moisture barrier
Rigid insulation
Both the moisture barrier and the insulation run risk of damage during concrete pouring
Heat loss through edge of slab

5. Note that, even with insulation beneath the slab, a considerable amount of heat can still be lost through the edge of the slab and the footing. This part of the slab normally has the highest heat loss, and the slab insulation does nothing to prevent this. This is not a serious problem, since the resulting warming of the footing and the soil around it is probably beneficial.

Windows and Shutters

FEATURE: INSTALL THERMAL SHUTTERS OR THERMAL SHADES ON ALL WINDOWS.

Passive solar design was incorporated into the house plans in order to take full advantage of sunlight as a factor in heating the house. The house is placed so that the side with the greatest number of windows is facing in a southerly direction.

The northern windows were redesigned to meet the minimum code requirements only, for example, five percent for bedroom windows. All northern facing windows included triple-glazing while the southern windows were standard double-glazed to allow infiltration of solar radiation. Optimum window size for passive solar gain was also taken into account in designing the south-facing windows. High-value insulated window shades were installed on all windows.

Jetstream Wood Furnace

FEATURE: INSTALL A JETSTREAM WOOD FURNACE AND 4,540 LITRES HOT WATER HEAT STORAGE TANK, WITH HEAT EXCHANGERS TO PROVIDE FORCED AIR SPACE HEATING AND DOMESTIC HOT WATER HEATING.

The most significant energy conservation feature which was included in the project was the installation of a combination wood-electric heating unit to supply heat for the entire house. The Jetstream wood furnace uses a wood-fired boiler to produce hot water for hydronic home heating systems.

Hydronic systems incorporate either a heat collecting water jacket around the combustion chamber or have heat exchanger tubes built in above the fire zone. Heated water is circulated through a network of pipes and heat is released through radiators or convectors in each room.

Boilers using high turbulence combustion can be combined with large water tanks for heat storage. The boiler is fired continuously at high temperatures until the storage water is fully heated. The house is heated by circulating the water from the storage tanks. When recharging is necessary, the cycle is repeated. This system is capable of achieving high efficiency ratings.

To heat the demonstration house and the domestic hot water supply, heat exchangers were placed in the heat storage tank. The house is heated by air forced through a water-to-air heat exchanger while the domestic hot water is via a water-to-water heat exchanger. Supplying the domestic hot water in this manner will displace a significant amount of electrical energy normally used by conventional hot water heaters.

To provide a backup to the wood boiler, electric immersion heaters were installed in the heat storage tank. Electricity was chosen as the backup energy source because of the low initial installation costs and because the electrical backup need not be used often. It was predicted that the wood system would be used almost exclusively due to its efficiency and convenience. Another importance factor which would encourage the use of wood only is the cost difference between electric and wood heat; electricity costs $12.00 per gigajoule (GJ) whereby wood costs only $3.00 to $4.00 per GJ.

PERFORMANCE

Unfortunately, heating fuel records (wood and electricity) were not maintained by the tenants who rented the house prior to its sale. Therefore, it is impossible to assess the amount of energy actually consumed.

It was predicted, however, that the heat loss of the building with the energy conservation features would be about 16,500 BTU per hour or about five kWh. This loss level requires about 400,000 BTU per day to heat. As a design temperature of -42^{o} C, the 4,540 litres heat storage tank is capable of storing about twice this amount meaning that the backup unit need seldom be used. It was recommended that the wood boiler required firing no more than once a day even in the coldest weather and only every several days in more moderate weather.

The heat loss calculations were based upon the following assumptions:

a. temperature difference of 55^{o}C (-45^{o}C outside and 10^{o}C inside),
b. all shutters closed,
c. house unoccupied,
d. 15 percent window area facing south and five percent facing north and
e. air changes per hour equal to 0.1.

Airtightness Testing

Following completion of the construction, a consultant was requested to undertake airtightness testing of the building. On May 28, 1982, an envelope area of 353 square metres in size and 474 cubic metres in volume was tested under 50 Pascals (Pa) of air pressure. Test conditions included no precipitation, high solar radiation and clear sky/cloud conditions. The temperature inside the house was $18^{o}C$.

Figures 5 and 6 indicate the results of the test. It was found that the building experienced 2.74 air changes per hour (ACPH) at 50 Pa of air pressure. Air change refers to the rate at which the total volume of air is exchanged for cold, outdoor air, by leaking in and out of the building - through open doors, around windows, through ceilings and walls, up the chimney and so on.

The air change rate of a traditionally constructed home ranges between four to eight ACPH at 50 Pa of air pressure. The recommended standards provided by the Canadian General Standards Board are 1.5 ACPH at 50 Pa for a normal conserver (R-2000) home and two to 2.5 ACPH at 50 Pa for energy efficient housing. Comparing the demonstration house to these standards confirms that the house is below the acceptable standards and it is concluded that more care was necessary when the air-vapour barrier was installed.

FIGURE 5

AIR TIGHTNESS TEST REPORT

MAY 28, 1982

IDENTIFICATION

- DATE May 28 1982
- TIME 12:30 P.M.
- CLIENT YTG
- ADDRESS #2 Chestnut
- PHONE NO. (RES.) _____ (BUS.) _____
- TECHNICIAN Don Willems
- TEST PURPOSE

☐ PRE-RETROFIT ☐ POST-RETROFIT
☑ NEW HOUSE TEST ☐ RESEARCH

- COMMENTS _____

DESCRIPTION

- CONSTRUCTION DATE _____
- WALL CONSTRUCTION _____
- NO. OF STORIES 1
- BASEMENT _____
- HEATING SYSTEM _____
- D.H.W. SYSTEM _____
- SIDING _____
- WINDOWS _____
- VENTILATION SYSTEM heat exchanger
- ENVELOPE AREA 353 m^2
- INTERIOR VOLUME (HEATED) 474 m^3

TEST CONDITIONS

OUTSIDE

- TEMPERATURE (T_o) —
- WIND (VEL. AND DIR.) _____
- RELATIVE HUMIDITY (RH_o) —
- AIR PRESSURE —
- PRECIPITATION Nil.
- SOLAR RADIATION high.
- SKY/CLOUD CONDITIONS clear.

INSIDE

- TEMPERATURE (T_i) 18°C.
- RELATIVE HUMIDITY (RH_i) —
- AIR PRESSURE —
- T_i/T_o DIFFERENCE _____

TEST RESULTS

PRESSURE(PA)	FLOW (M^3/S)
10	0.145
15	0.165
20	0.193
25	0.233
30	0.261
35	0.295
40	0.320
45	0.342
50	0.367
55	
60	

PRESSURIZED ☐
DEPRESSURIZED ☑

EXPONENT(N) 0.610
CONSTANT(C) 0.033
CORRELATION 0.9925

AIR FLOW AT 10 PA. 0.13 M^3/SEC
AIR FLOW AT 50 PA. 0.36 M^3/SEC
E.L.A. 0.05 SQ.M. @ 10 PA.
AIR FLOW/UNIT AREA AT 50 PA. 1.02 L/S/m^2
AIR CHANGES/HR. AT 10 PA. _____
AIR CHANGES/HR. AT 50 PA. 2.74

HOUSE CONDITIONS

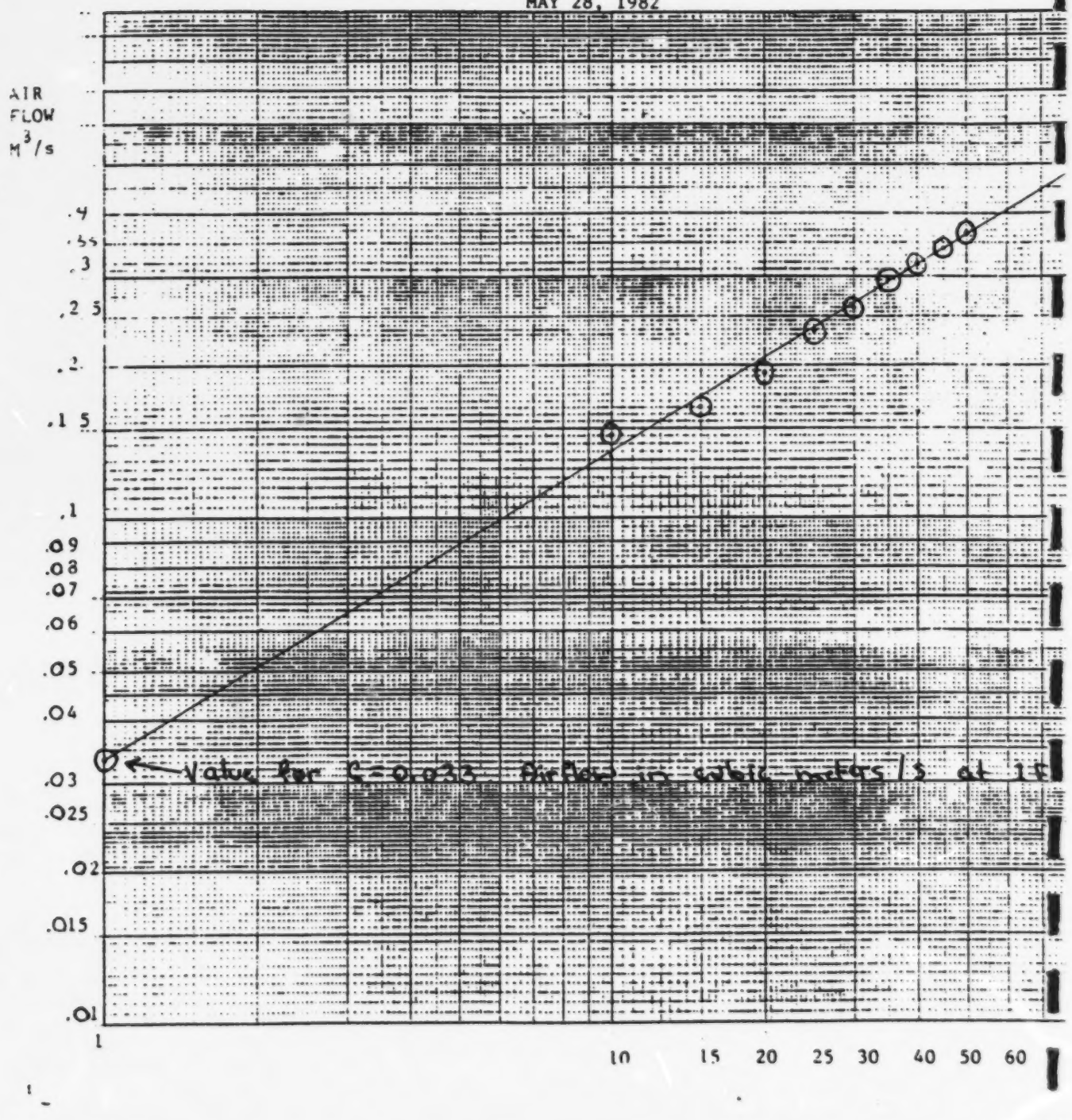
- VENTS: ☐ OPEN ☐ SEALED
- FIREPLACE: ☐ CLOSED ☐ BLOCKED ☐ SEALED
- FURNACE: ☐ OPEN ☐ SEALED

COMMENTS House equipped with heat exchanger. Outlets sealed

FIGURE 6

AIR LEAKAGE PROFILE

MAY 28, 1982



PRESSURE DIFFERENCE ACROSS BUILDING ENVELOPE

(PASCALS)

On June 25, 1984, air leakage testing was conducted again to determine whether damage from excessive moisture build-up during installation of the water storage tank damaged the air-vapour barrier. The results indicated 2.74 ACPH at 50 Pa of air pressure and an airflow of 1.02 $L/s/m^2$. These test results are the same as the previous tests; therefore, it was concluded that the barrier had not been damaged.

Jetstream Furnace System

As mentioned earlier, the jetstream furnace system was installed improperly. Errors in pipe sizing, ducting design, positioning of valve controls, etc. rendered the entire system inoperable for better part of a year following the occupancy of the house by the first tenants.

Considerable time and additional money above the initial installation costs were necessary to make the jetstream furnace system operational. Finally, it was concluded that the best approach would be to solicit a consultant familiar with the technology to undertake a thorough assessment of the problems and solutions required to make the system work. The measures recommended by the consultant as necessary to correct the problems was a complete redesign of the system. These measures were estimated to cost $1,465; however, the consultant guaranteed that for the additional cost, the system would operate in an efficient and reliable manner.

The full assessment provided by the consultant is attached in Appendix A for information purposes only. The analysis provided by Wayne Kale includes describing how the system should and would work if properly installed, how the system was installed by the subcontractors, the problems rending the system inoperable, recommendations to make it work and an estimation of the necessary material and labour costs to put the system into operation.

BUDGET REVIEW

The house was estimated to cost: $11,000 for the lot, $66,000 for the building and $7,820 for the energy conservation features. The total was $84,820.

Table 1 outlines the estimated and actual costs of the demonstration project. Originally, the energy conservation features were estimated to cost $7,800; however, because of major problems associated with the installation of the jetstream furnace system, the actual costs were considerably higher at approximately $29,500.

TABLE 1

ESTIMATED AND ACTUAL PROJECT COSTS

Item	Budget	Actual
Extra 2 x 4 studding	$ 400.00	$ 400.00
Insulation (walls & basement floor)	1,820.00	3,303.25
Shutters and Windows	1,300.00	1,581.46
Jetstream Furnace, Electric hook-up heat storage tank, DHW heat exchanger and related items	3,500.00	23,473.95
Air-to-air heat exchanger	800.00	688.50
Total	$7,820.00	$29,447.16
Information transfer	3,500.00	1,000.00 (estimated)
Total	$11,320.00	$30,447.16

CONCLUSIONS AND RECOMMENDATIONS

The project was concerned with reducing, as much as possible, the amount of fuel consumed in heating the single-family dwelling built by the students of the Yukon College. The extra insulation incorporated into the building during the construction period should have decreased the total amount of fuel needed for maintaining a comfortable indoor climate for the residents of the house. However, because of the problems associated with installing the jetstream wood furnace system, actual fuel savings cannot be assessed at this time.

The additional work recommended and undertaken by the consultant did get the system working. The new owner of the house estimated that approximately six cords of wood were required to heat the house during an average temperature winter season.

The jetstream heating system used in the demonstration project is a relatively new development in wood heating equipment and it would be unfair to pass judgement on the system based upon the disappointing results of the Yukon College demonstration project.

The most significant result of the project is to demonstrate the need to provide local contractors with technical training prior to or along with the introduction of innovative energy efficient technology.

APPENDIX A

An Analysis of
the Jetstream Heating System
at 2 Chestnut Street Whitehorse

Report prepared for
Yukon Housing
By Wayne Kale
September, 1982

Introduction

On August 25, 1982 Dave Thompson from Yukon Housing and I examined the jetstream heating system at 2 Chestnut Street Whitehorse. The present tenant, Werner Holden indicated that he had tried unsuccessfully to operate the system for three days and to his knowledge the previous tenant also was not able to use the furnace to supply heat for the house. Yukon Housing was interested in an assessment of the jetstream installation and the expected cost to make the system operational.

The jetstream heating system isarecent inovation in wood heating furnaces (see Harrowsmith No. 27, April 1980). The "super furnace" (as labelled by Harrowsmith) works on the principle that energy from wood is best utilized by extracting that energy and storing it in a hot water reservoir, a much more usable and convenient energy source. Typical jetstream installations use a low-head circulator to pump water through the jetstream's boiler to a 500 to 1000 gallon storage tank. Energy from the storage tank may be used in either a hot water or hot air heating system.

The jetstream heating system at 2 Chestnut Street was installed by the Yukon Vocational School during 1981 as part of an experimental project. Work was done by several subcontractors, each responsible for one of the four subsystems (plumbing, electrical, jetstream furnace, and storage tank).

Evaluation of existing Jetstream heating system

Although the jetstream system may have functioned to some degree when first installed, it never could have functioned properly by obtaining the high degree of efficiency claimed by Hampton Jetstream, the manufacturer of the furnace. I observed major deficiencies in the systemsdesign and installation.

The schematic diagram for the plumbing system shows why the system cannot function properly. The jetstream system consists of three components: 1) a jetstream boiler, 2) a hot water storage tank and 3) a duct heat exchanger that must be connected by copper pipe. The copper piping must be properly sized and routed to transfer water to and from the three components. The jetstream boiler provides energy to the system, the duct heat exchanger extracts energy, while the storage tank stores energy. The jetstream system with 4 zone valves and 1 circulator is designed to function in three operational modes:

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1) charge up cycle - The valves direct relatively cold water from the storage tank to the jetstream boiler and then back to the storage tank as relatively hotter water. This mode should exist whenever the jetstream furnace temperature is hotter than the storage temperature (typically when furnace is lit) and the house does not need heat.
2) draw down cycle - The valves direct relatively hot water from the storage tank to the duct heat exchanger and then back to the storage tank as relatively colder water. This mode should exist when the house requires heat, the storage tanks temperature is greater than 110° F, and the jetstream furnace is not on.
3) immediate heat - The valves direct relatively cold water from the storage tank through the jetstream boiler where the water becomes hotter. Then the water is directed through the duct heat exchanger where it provides heat for the house before returning to the storage tank. Depending on the heating demand by the house, the water returning to the storage tank may be colder than that leaving the tank. This mode exists whenever the house requires heat while the jetstream furnace is on.

As summarized on the plumbing schematic drawing the zone valves at 2 Chestnut Street are improperly positioned to provide the three heating modes. In order for the system to function at all, valve 3 must remain permanently closed and in fact is disconnected from the electrical control panel. Similarily although valve 2 may modulate it does not affect the system. It must remain closed except for the case where it is upstream of a closed zone valve.

At 2 Chestnut Street, the jetstream system has been plumbed as two separate waterflow loops. The first is controlled by zone valve 1 which directs water on the "charge up" cycle through 1¼ inch supply lines. The second is controlled by zone valve 4 which directs water in the "draw down" cycle through 3/4 inch supply lines. The "immediate heat cycle" does not exist as water cannot go directly from the jetstream boiler to the duct heat exchanger. Instead the 2 Chestnut Street system has a "both" cycle option.

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It is extremely doubtful whether the 3/4 inch supply line can provide sufficient water volumes to heat the house if the jetstream furnace is on. This is because the majority of water (75+%) will flow through the 1¼ charge up loop.

Therefore under harsh winter conditions (outdoor temperatures less than -30°C) the house will not be adequately heated by the jetstream system while the jetstream furnace is lit (approximately 20% of the time). Furthermore if occupants return to a cool house (less than 50°F) and the water tank temperature is less than 100°F), it may take the jetstream several hours before sufficient excess heat is produced to warm the house up. This is because the "immediate heat" cycle which assigns heating priority to the house does not exist.

Another major problem with the plumbing system is the 500 feet of 3/4 " copper pipe that acts as a water-to-water heat exchanger in the tank. Because the pipe is strewn "helter skelter" in the tank, it is extremely likely that the plumbing system will "air lock" wherever there is a high point in the water line. If this happens, then the pump will not circulate the water and the system will not function at all. (it is probable that this is why neither the present or past house tenant were able to get the system to work).

At several points in the plumbing system there are extreme water flow obstructions. Around zone valves 2 and 4, the pipe is reduced to 3/8" from 1¼" and 3/4" pipe respectively. These restrictions negate using 1¼" supply lines and are contrary to the installation instructions recommended by Hampton jetstream.

Other minor problems with the plumbing system are:

1) the pump is horizontally installed at a relatively high point in the plumbing system. It should be installed at a low point and vertically.
2) the surface mount aquastat only senses the tank temperature when the pump is circulating water. However, it controls the pump. If the water line does not transmit enough heat up to the aquastat then the pump will not turn on during the "draw down" cycle. An immersion aquastat should have been installed.
3) the plumbing line leaks where it enters the jetstream boiler.
4) the level indicator for the tank was never installed.

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5) only 2" of styrofoam insulation was installed on the tank top. Since the top of the tank is the hottest part of the tank, the insulation should be increased to R 30 (6" of styrofoam)

Although the jetstream furnace was not fired up during the inspection, it appeared to be properly installed. Furthermore, the electrical contractor indicated that the electrical system was modified from that supplied from Ark Solar Products, to accommodate the improperly installed plumbing system. Although none of the zone valves would respond when the relays were tripped, I do not suspect that there are major problems in the electrical system.

Recommend corrective measures

The present 2 Chestnut Street jetstream system is a pressurized system. Water in the supply lines is pressurized and separate from that in the storage tank. The major advantage of the pressurized system is that higher boiler temperatures can be developed than with an unpressurized system. In addition, only about 70 gallons of water must be treated to protect the boiler as opposed to an unpressurized system in which about 900 gallons need to be treated.

To repair the pressurized system, the 500 ft. of 3/4" pipe in the storage tank, must be re-organized into at least two vertically stacked coils. These coils would allow air bubbles to pass through them and thus prevent air locking. The coils should be soldered to supports to keep the pipe spaced and stacked properly. Since there is only a 3 X 3 opening in the top of the tank, either the coil construction must be done inside the tank or many smaller coils must be constructed. I would estimate that to construct these coils might take up to 40 hours.

Even if the coils are properly constructed, there is no guarantee that they will adequately exchange heat with the water in the tank. Heat transfer depends on the temperature differential between the heat exchanger and water in the tank as well as the rate of water flow through heat exchanger.

Since the construction of heat exchanger coils from the 500 feet of 3/4" pipe is expensive and may not work properly, I recommend that the pressurized system be replaced by an unpressurized system.

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To odify the existing 2 Chestnut Street jetstream system to an unpressurized system the following steps should be taken (see schematic diagram of proposed jetstream plumbing system)

1) the pressure tank, pressure make-up valve, and 500 ft. of 3/4" copper pipe (tank heat exchanger) should be removed.

2) the 3/4" "draw down" loop must be replaced by 1¼" copper lines which must extend to bottom of tank.

3) Depending on pump specifications, "ie how much water it will draw up" the pump inlet may have to be moved to the present tank drain position (N.B. the pump can be used to drain tank if necessary)

4) the automatic air vents must be replaced by manual vents at high points of the plumbing.

5) the surface mount aquastat must be replaced by an immersion aquastat. The aquastat bulb can be put down the tank sensor well.

6) The back flow preventor and the water supply line should be installed at a low point in the plumbing loop preferably upstream of the pump.

7) the plumbing should be done in accordance to the plumbing schematic drawing and 1¼" lines should be used throughout.

8) the boiler aquastat (see jetstream manual must be reset to 180° F)

9) the electrical system must be redone to conform to wiring diagram supplied by Ark Solar Products.

10) when the entire system is functional, enough water treatment must be added to the tank to inhibit boiler corrosion.

11) the jetstream sensors must be checked with boiler temperature guage.

12) to facilitate future servicing the jetstream fan housing must be modified.

Repair Estimate

From experience gained installing my own jetstream system, I am willing and able to do the necessary modifications to the 2 Chestnut Street Jetstream System. However, since I am not a plumber or electrician by trade, I have provided two estimates of the total cost of repairs. The total material cost depends on whether existing components are in working order, something that cannot be determined until the system is taken apart. I expect the total materials to cost $755 up to a maximum amount of $1315. The expected labour cost is $710 up to a maximum of $950. There will be no labour charge, unless the system is made completely functional as described in the jetstream manual.

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Conclusion

The jetstream heating system is, without a doubt, a major break through in wood heating systems. The concept of storing energy from wood in a more usable medium is the "right way" to use energy from wood. It is efficient, practical, convenient, and safe (no creosote).

The jetstream heating system at 2 Chestnut Whitehorse has not functioned to date because it was improperly installed. With the modifications described in this report, the system can be made to operate in an efficient and reliable manner.

Repair Estimate

Materials*	Expected	Maximum
Zone valves (110 each)	$220	$440
Submersible aquastat	75	75
Level indicator (if wanted)	0	150
Pipe fittings	50	100
Copper pipe	40	80
water treatment	250	300
styrofoam insulation	100	150
wire	10	10
electrical connectors	5	5
solder, flux, etc.	5	5
	$755	$1315

*Only materials needed will be purchased. It would be prefered if Yukon Housing would purchase materials directly. Note: Cost of new materials may be off-set by salvaged materials such as 2 3/8" zone valves, surface mount aquastat, 500 feet of 3/4" copper pipe, pressure tank, and pressure make-up valve. New price of these components was about $1400.

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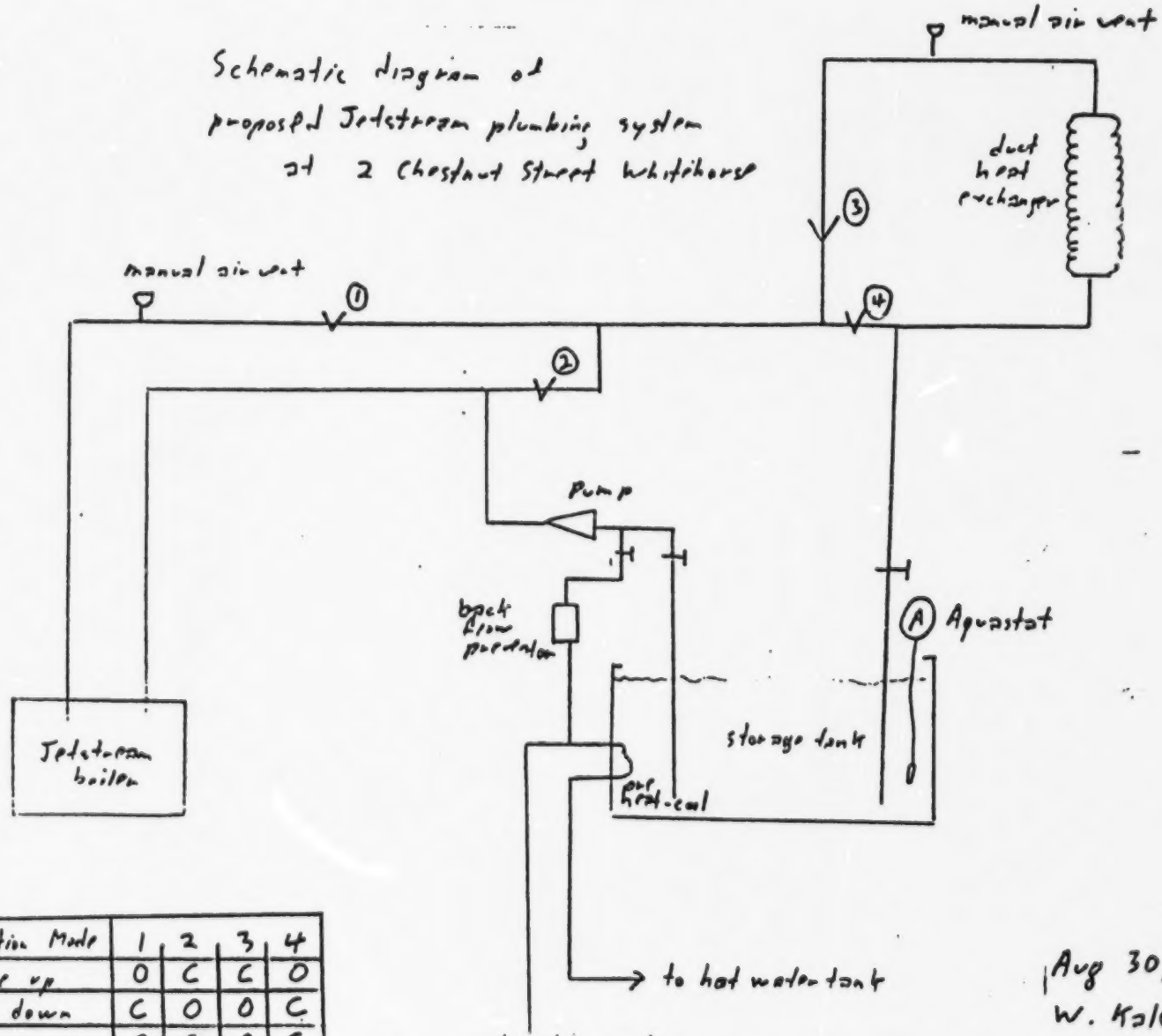
	Expected hours	cost	Maximum hours	cost
Initial consultation	2.5 hr.	$ 50	2.5 hr.	$ 50
Report	4.0	$ 80	4.0	$ 80
Plumbing	16.0	$320	24.0	$480
Electrical	4.0	$ 80	8.0	$160
Insulation added to tank	2.0	$ 40	2.0	$ 40
modifications to jetstream fan	2.0	$ 40	2.0	$ 40
Testing and calibration	4.0	$ 80	4.0	$ 80
Instruction of operators	1.0	$ 20	1.0	$ 20
	35.5	$710	47.5	$950

*costs calculated at $20.00 per hour

Total

	Expected	Maximum
Materials	$755	$1315
Labour	$710	$ 950
Total	$1465	$2265

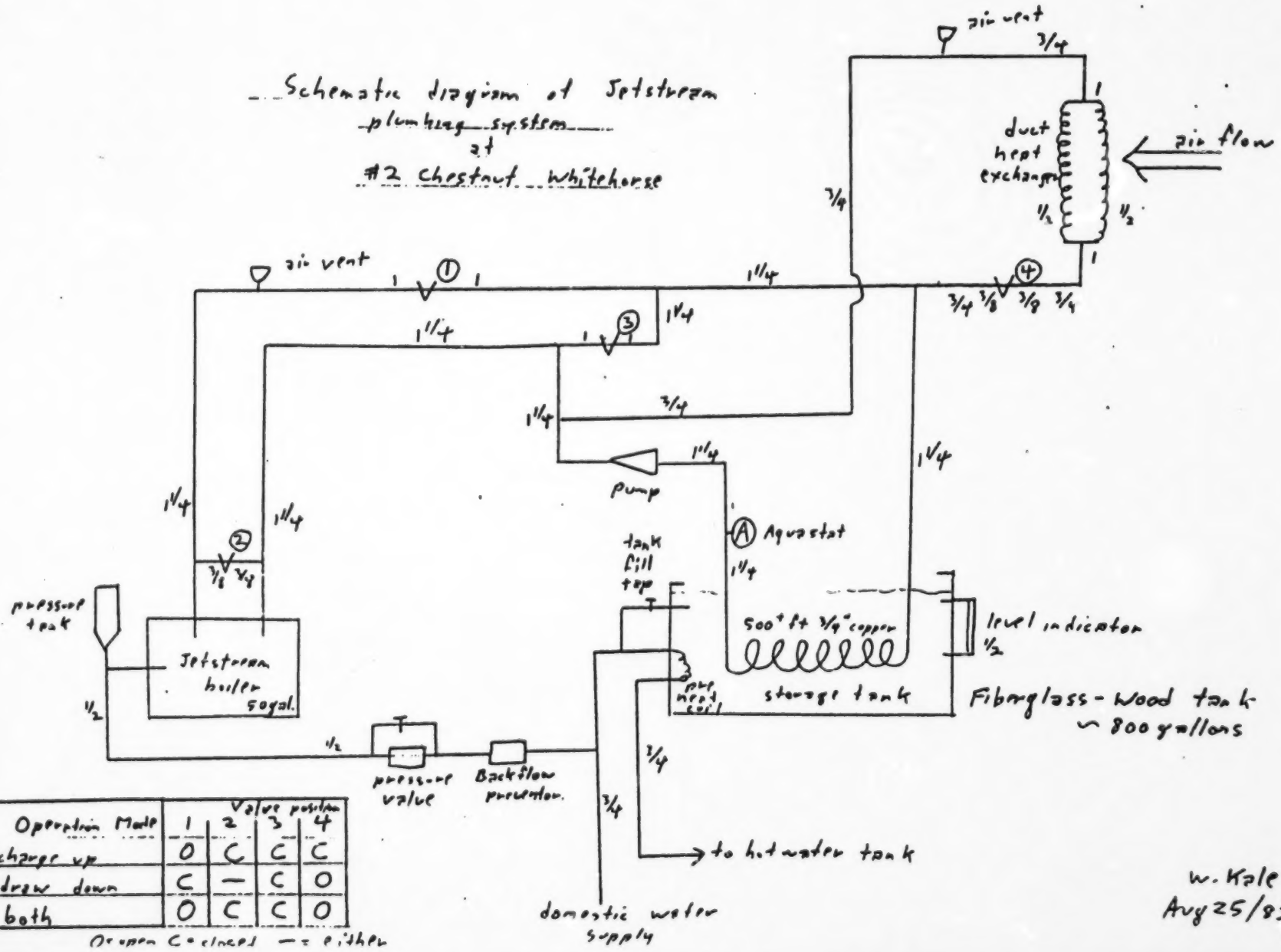
Schematic diagram of
proposed Jetstream plumbing system
at 2 Chestnut Street Whitehorse



Operation Mode	1	2	3	4
charge up	O	C	C	O
draw down	C	O	O	C
[illegible]	C	C	C	C

Aug 30/82
W. Kale

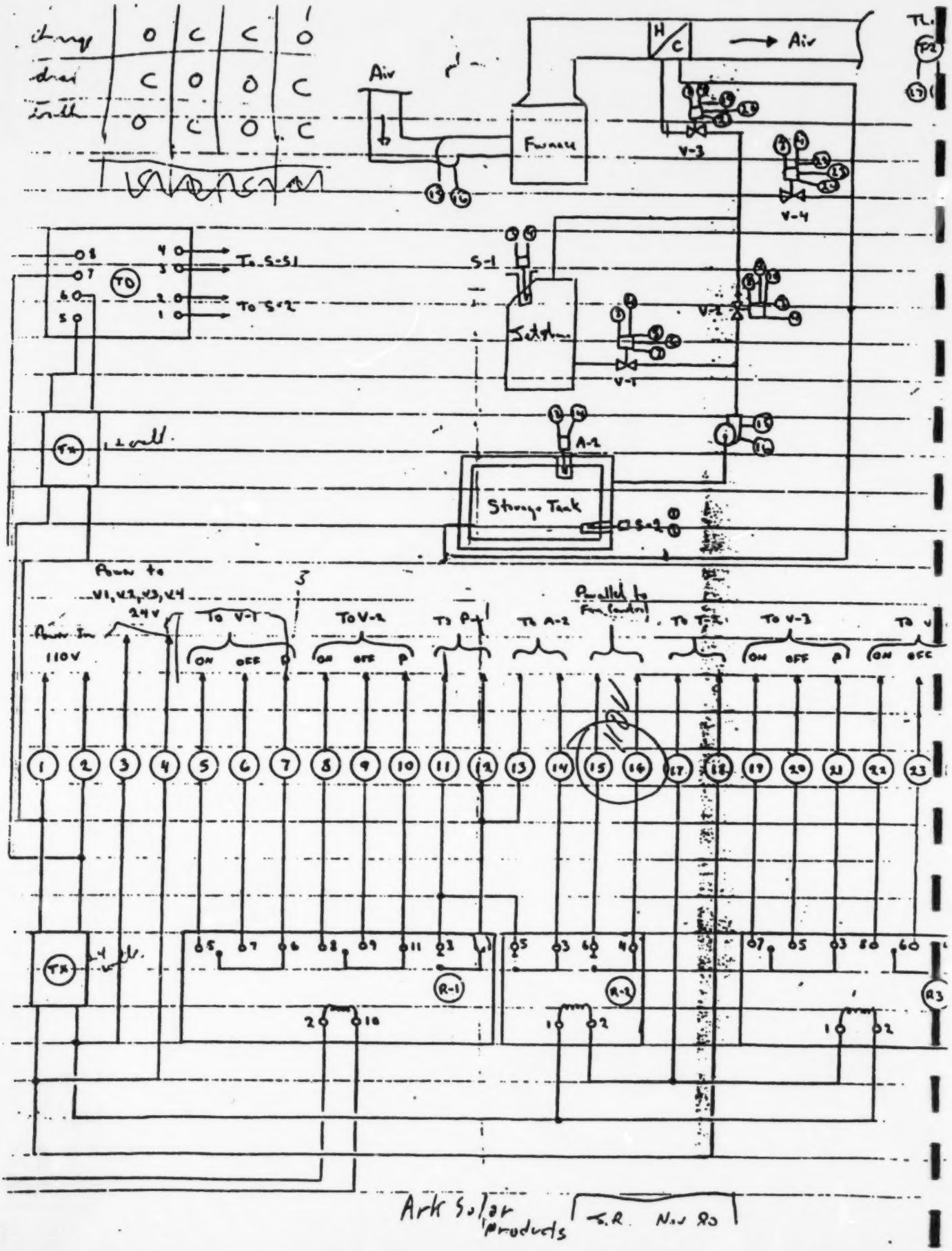
Schematic diagram of Jetstream plumbing system at #2 Chestnut Whitehorse



Operation Mode	Valve position 1	2	3	4
charge up	O	C	C	C
draw down	C	—	C	O
both	O	C	C	O

O = open C = closed — = either

W. Kale
Aug 25/82


Air
Furnace
H/C
Air
V-3
V-4
V-1
V-2
S-1
Switch
A-2
Storage Tank
S-2
To S-1
To S-2
TO
TX
Power to V1, V2, V3, V4
24V
Power In
110V
To V-1
To V-2
To P-1
To A-2
Parallel to Fan (outlet)
To T-1
To V-3
ON
OFF
P
R-1
R-2
R3
Ark Solar Products
S.R. Nov 80

Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

Yukon
Department of Economic Development and Tourism

Yukon College New Home Construction

Final Project Summary

Canada/Yukon Conservation and Renewable Energy Demonstration Program

Project No.
3766-4-4

Date:
February, 1985

Sectors:
Institutional/ Commercial

Project Locations:
Whitehorse

Technology:
Conservation

Jurisdiction:
Yukon

Project Manager:
Robert E. Collins

Status:
Complete

Simple Payback:
N/A

Purpose:

1. To demonstrate energy savings from constructing an energy efficient house.
2. To provide direct training for students enrolled in carpentry courses on methods and technology of energy conservation features.

Description:

A single dwelling residence was constructed by the Yukon College carpentry students which included the following features: air-vapour barrier, double stud walls, additional insulation in walls, ceiling and basement floor, Jetstream wood furnace and thermal window shutters.

Contributors:

Canada/Yukon $11,320

Demonstrated Benefits:

Transmittal of the knowledge and technical expertise associated with energy conservation building construction to college students and local contractors.

Further Information

Robert E. Collins, Program Manager, Energy and Mines Branch, Department of Economic Development and Tourism, Government of Yukon, P.O. Box 2703, Whitehorse, Yukon Y1A 2C6 phone (403) 667-5471.

Economic Analysis:

Because of problems associated with installing the wood furnace and because the tenants occupying the house did not maintain fuel records, it is impossible to assess the energy savings at this time. However, cost overruns on the installation of the Jetstream were horrendous bringing the total project costs up to $30,000.

Information Transfer:

1. The demonstration project was scheduled to allow professionals and the general public free access during the building phase and on weekends after construction was completed and the building occupied.
2. A final report will be produced dealing with the energy conservation measures incorporated into the construction plans for the house.

Technical Details:

It was predicted that the heat loss of the house with the energy conservation features would be approximately 16,500 BTU per hour which requires about 400,000 BTU per day to heat. The house is heated by a Jetstream wood boiler. At a design temperature (-43^{o} C), the 4,540 litres heat storage tank is capable of storing about twice this amount.